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ABSTRACT

This study investigates the physical characteristics, body composition, cardiovascular and pulmonary functions, and aerobic capabilities of male and female long distance runners. Eleven runners volunteered to take tests to determine background information, body fat, oxygen uptake, and running time and pace. Conclusions made from this study include: (1) Male and female runners are slight in build with little body fat and possessing large lung volumes; (2) Male marathon runners are taller, heavier, and have less relative body fat than female runners; (3) Male and female runners did not differ in aerobic capabilities; (4) Experienced female runners are able to work at a high fraction of their aerobic capacity as are all male runners. Findings are illustrated in tabular form. (CJ)

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BODY COMPOSITION AND AEROBIC REQUIREMENTS OF MALE AND FEMALE MARATHON RUNNERS

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Large numbers of people are currently engaged in long-distance running. Participants are of both sexes, of all ages, from all walks of life and run for a variety of reasons. Of particular interest is the wide popularity of marathon running exemplified by the 300% increase in the number of marathon races held in this country from 1968 to 1976 (Maron & Horvath, 1978).

Considerable information is accumulating on the physical characteristics, body composition and cardiovascular endurance of elite class middle-distance and, to a lesser extent, long-distance male runners (Costill, Bowers & Kammer, 1970; Novak, Woodward, Bestit & Mellerowicz, 1977; Saltin & Astrand, 1967; Sprynarova & Parizkova, 1971). Information on elite class female distance runners, although forthcoming more slowly, is also available (Brown & Wilmore, 1971; Novak et al., 1977; Wilmore & Brown, 1974; Wilmore, Brown & Davis, 1977). However, most of the studies on women "distance runners," involve subjects who compete in events considerably shorter than 5,000 meters. In fact, only one study has been located specifically dealing with women marathon runners (Jordan, 1977). The author of that study made no attempt to classify the runners, stating only that they were running 20-90 miles/week in preparation for various marathon events.

It is desirable to describe the physical and performance characteristics of elite athletes in order to understand the physiology of men's maximal capabilities. We believe it is also important to study the not-so-elite performer

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in view of the fact that of thousands of participants, only a few are elite performers. The characteristics, abilities, limitations, and adaptations of the "average" performer will contribute not only to a more complete understanding of the human organism, but to the stresses and benefits of marathon running.

The present study has investigated the physical characteristics, body composition, pulmonary function, and aerobic capabilities of adult male and female marathon runners. In addition, oxygen uptake values obtained at various submaximal treadmill running speeds were used to estimate the aerobic requirements for performing a particular marathon event.

Methods

Seven male and four female long distance runners training for the December 2, 1978 Fiesta Bowl Marathon (Scottsdale, Arizona) were subjects for this investigation. All participants had previously completed several marathon races. The subjects were engaged in serious endurance training, running 37 to 120 miles per week, but none were considered elite marathon performers. Table 1 presents the physical characteristics of the subjects.

Upon volunteering for the study, each subject completed an informed consent form and a questionnaire on current and prior health status, training activities, running performance and dietary habits. Forced vital capacity (FVC) and residual volume (RV) were obtained in the sitting position utilizing a 13.5 L Collins Respirometer and the helium dilution method. Body density (D) was calculated from hydrostatic weighing conducted in a fiberglass tank in which a swing seat was suspended from a 15 kg scale. The weighing procedure as outlined by Behnke and Wilmore (1974) was repeated 6 to 10 times or until 3 similar readings were obtained. The calculation of percent body fat was according to the formula of Brozek, Grande, Anderson and Keys (1963). Table 2 presents the pulmonary function and body composition data obtained.

On a subsequent laboratory visit, each subject completed three 6-minute submaximal exercise loads selected according to prior and target marathon performance times with intervening 3-minute runs at 6 mph. The submaximal exercise loads were, in progression, 1 mph slower than target pace, target pace, and 1 mph faster than target pace. For example, if a subject expected to complete the marathon in 2:48:00, he/she would have to average 6:36 per mile, a 9 mph pace. This subject would, therefore, complete 6 minutes of running at 8 mph, 9 mph and 10 mph. Expired air was collected in meteorological balloons via a Daniels' collecting tube between minutes 4-5 and 5-6 of each run. Samples of the expired air were analyzed for O_2 and CO_2 via Beckman OM-11 and LB-2 electronic gas analyzers. The analyzers were calibrated before and after each experiment with standardized gases previously checked with a Lloyd-Gallenkamp apparatus. The volume of air expired was evacuated into a 120 L Tissot spirometer and corrected to STPD. The 6-minute running period was sufficient for each subject to achieve steady-state according to heart rate determinations and oxygen uptake measurements.

Following the third 3-minute intervening period at 6 mph, each subject completed a multi-stage running treadmill procedure designed to bring the subject to maximum oxygen uptake ($\dot{V}O_2$ max) within 4 to 6 minutes. The treadmill grade was elevated 2½% each minute following a 2-minute initial exercise load. The speed and starting treadmill grade were determined after examination of submaximal $\dot{V}O_2$ data and in consultation with the subject. The test was completed when the subject could not finish a work bout. $\dot{V}O_2$ max was considered to be achieved when two consecutive determinations differed by less than 2.10 $ml.kg^{-1}.min^{-1}$ with increase in treadmill grade (Taylor, Buskirk & Henschel, 1955). During the entire procedure, a large fan (facing the subject) was used to aid body cooling, and to simulate the air resistence of outdoor running.

Results and Discussion

Table 3 presents the results of the treadmill test for maximal oxygen uptake. There was no significant difference in $\dot{V}O_2$ max expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ between the male and female marathon runners of this study. However, to suggest that differences or non-differences exist between male and female marathon runners is inappropriate with such small sample sizes for each sex. Furthermore, the female runners were more accomplished, in the relative sense, than the male runners, placing 2nd, 3rd, 5th and 8th in the women's division of the Fiesta Bowl Marathon. One of the male runners won the over 40 male division. The other male runners did not accomplish notable field place.

The mean female subjects $\dot{V}O_2$ max value of 59.2 $ml \cdot kg^{-1} \cdot min^{-1}$ was lower than that reported for elite distance runners by Brown and Wilmore (1971), but equal to or greater than that reported for other "long-distance" runners (Daniels, Krahenbuhl, Foster, Gilbert & Daniels, 1977; Jordan, 1977; Novak, Bierbaum & Mellerowicz, 1973; Saltin & Astrand, 1967; Wilmore & Brown, 1974).

The male marathon runners of this study had $\dot{V}O_2$ max values considerably below those previously reported for elite long distance runners (Costill & Fox, 1969; Daniels et al., 1977; Pollock, 1977) and were also below the values reported for "good" runners (Costill, Thomason & Roberts, 1973; Pollock, 1977). This value ($\bar{X}$ $\dot{V}O_2$ max = 58.4 $ml \cdot kg^{-1} \cdot min^{-1}$) corresponds to what would be expected when considering the type of training these men engaged in--moderate distance at slow to moderate pace. Three of the female subjects, on the other hand, engaged in much faster steady-state running mixed with high intensity interval work.

Figure 1A presents mean (± S.E.) oxygen uptake values at each submaximal treadmill speed for the male and female subjects. There were no significant differences between the males and females. The females ran faster submaximal running bouts than the males because of their faster marathon prediction times

(and subsequent performance). These values are very similar to the values reported by Daniels et al. (1977) for Canadian Olympic runners, and support their conclusion that there are no sex differences in the aerobic demands of running when the submaximal range of speeds used are common to both groups and when the runners are similar in ability.

Figure 1B presents a comparison of the fractional utilization of the aerobic power of each group at each submaximal running speed. There were no significant sex differences in the fractional utilization of aerobic power at these running speeds.

Individual regression equations for $\dot{V}O_2$ and treadmill running speed and the actual Fiesta Bowl marathon race pace were utilized to estimate the aerobic requirement of each subject for that event. Table 4 presents grouped results. The male subjects finished the race in 192.67 minutes at an average running pace of 8.4 mph and consumed an estimated 44.41 ml of $O_2 \cdot kg^{-1} \cdot min^{-1}$. These runners accomplished this task utilizing approximately 75.8% of their aerobic capacity. The female runners ran slightly faster finishing the race in 178.75 minutes at an average pace of 8.8 mph, and required an estimated 48.51 ml of $O_2 \cdot kg^{-1} \cdot min^{-1}$. The women utilized approximately 81.9% of their aerobic capacity at this pace.

There were no significant sex differences in race time, race pace, estimated aerobic requirement, or estimated fractional utilization of aerobic power for the marathon race in this study. These results suggest that there were no sex differences in the aerobic efficiency with which these subjects ran the marathon event. It should be emphasized, however, that a larger sample size for each sex, and a more representative subject selection, might alter these results.

The subjects of this study showed the ability to utilize a large fraction of their aerobic capacity during actual competition. Costill and Fox (1969)

reported that elite male marathoners employed approximately 75% of their $\dot{V}O_2$ max during a marathon race. Our data substantiates this for female subjects as well as for more "average" male runners.

It has been estimated that most marathoners require about 2400 kcal to complete a marathon, and that Derek Clayton (the world's fastest marathoner at 2:08:33) required approximately 2656 kcal (Costill, 1972; Costill & Fox, 1969). Using mean values for the estimated $\dot{V}O_2$ at average race pace, body weight and race time, and assuming a respiratory ratio of 0.85, the male subjects in the present investigation required approximately 12.1 J (2903 kcal) and the female subjects required 9.2 J (2191 kcal) to complete the 42.2 km distance.

Conclusions

Within the limitations of this study, the following conclusions seem justified:

1. Male and female marathon runners may be described as being slight in build, with little body fat and possessing large lung volumes. The marathon runners of this study did not differ significantly from those previously described (Brown & Wilmore, 1971; Kaufmann et al., 1974; Pollock et al., 1977; Raven, 1977; Wilmore et al., 1977).
2. Male marathon runners are taller, heavier, and have less relative body fat than do female marathon competitors.
3. The male and female marathoners studied here did not differ in aerobic capability as indicated by $\dot{V}O_2$ max, $\dot{V}_E$ at $\dot{V}O_2$ max, R at $\dot{V}O_2$ max, HR at $\dot{V}O_2$ max or ventilation equivalent at $\dot{V}O_2$ max.
4. Experienced female runners are able to work at a high fraction of their aerobic capacity during marathon competition as are male runners.
5. No significant differences in the variables studied occurred between the male and female subjects of this investigation.

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TABLE 1

THE PHYSICAL CHARACTERISTICS OF THE SUBJECTS

	Males (n=7)	Females (n=4)	P
Age, yrs.	30.6±8.3	28.5±5.3	n.s.
Height, cm.	180.1±5.1	166.6±5.5	0.001
Weight, kg.	69.8±5.4	52.0±8.4	0.001
B.S.A., m^2	1.87±0.09	1.56±0.13	0.001
Training, miles/week	66.7±27.9	80.8±14.1	n.s.

Values are means ± S.D.

TABLE 2

PULMONARY FUNCTION AND BODY COMPOSITION

OF MALE AND FEMALE MARATHON RUNNERS

	Males (n=7)	Females (n=4)	P
Forced Vital Capacity, ml	5378±394*	4170±412*	0.001
Residual Volume, ml	2000±562*	1571±201*	n.s.
Density	1.084±0.008	1.074±0.002	0.05
% Body Fat	7.3±3.2	11.4±0.7	0.05
LBM, kg.	64.7±5.6	46.1±7.7	0.001
Fat wgt., kg.	5.0±2.3	5.9±0.9	n.s.

Values are means ± S.D.

* BTPS

TABLE 3

AEROBIC POWER OF MALE AND FEMALE MARATHON RUNNERS

	Males (n=7)	Females (n=4)	P
$\dot{V}O_2$ max, $ml \cdot kg^{-1} \cdot min^{-1}$	58.41±5.0	59.2±7.1	n.s.
$\dot{V}_E$ at Max, $l \cdot min^{-1}$	143.6±34.3	108.85±15.44	n.s.
R at Max	1.20±0.06	1.15±0.07	n.s.
HR at Max	182.8±7.5	191.5±16.0	n.s.
O_2 pulse at Max, ml	22.3±3.1	16.0±2.4	0.01
$\dot{V}_E/\dot{V}O_2$ at Max	35.0±5.1	35.7±2.5	n.s.

Values are means ± S.D.

TABLE 4

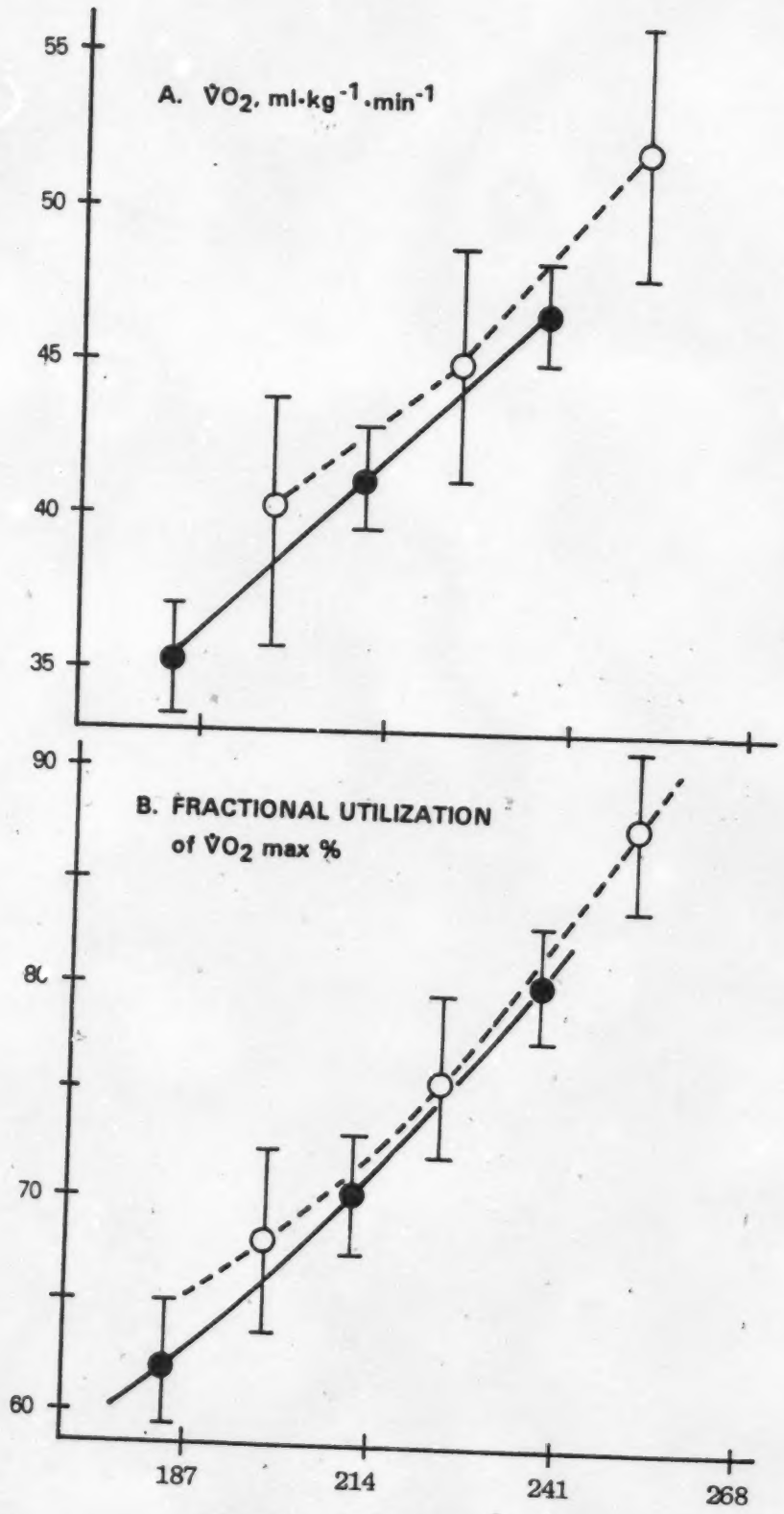
ESTIMATED AEROBIC REQUIREMENTS OF MALE AND FEMALE MARATHON RUNNERS

	Males (n=7)	Females (n=4)	P
Race time, min	192.7±33.8	178.8±10.8	n.s.
Race Pace, $m \cdot min^{-1}$	224.8±40.0	236.5±13.8	n.s.
Estimated Race $\dot{V}O_2$, $ml \cdot kg^{-1} \cdot min^{-1}$	44.41±7.12	48.51±6.60	n.s.
Estimated Race, % $\dot{V}O_2$ max	75.8±8.3	81.9±3.4	n.s.
Energy requirement	2903 Kcal (12.1 J)	2191 Kcal (9.2 J)	

Values are means ± S.D.

Figure Legend

Figure 1. A. Oxygen uptake ($\bar{x} \pm$ S.E.) of male and female marathon runners at various submaximal treadmill running speeds. B. Fractional utilization of $\dot{V}O_2$ max (%) ($\bar{x} \pm$ S.E.) of the same runners at submaximal treadmill running speeds. Open circles in A and B indicate females, closed circles indicate males.


55
50
45
40
35
A. $\dot{V}O_2$, ml·kg^{-1}·min^{-1}
90
80
70
60
B. FRACTIONAL UTILIZATION
of $\dot{V}O_2$ max %
187
214
241
268
TREADMILL RUNNING PACE m·min^{-1}